

Calculating Change in Groundwater Storage Using Groundwater Level Data

California Water Plan Update 2013 – Task Item 4

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California Department of Water Resources

May 29, 2013 Webinar Presentation

Overview of Presentation

- Introduction (5min)
- Data Types and Availability (10min)
- Other Methods to Calculate Change in GW Storage (5min)
- Estimating Change in GW Storage – Task 4 Methodology
 - Part 1: Synopsis, Goals, Assumptions, Key Concepts (35min)
-----BREAK-----
 - Part 2: Workflow Process (60min)
-----BREAK-----
- Recommendations and Wrap-Up (10min)



Introduction

- Background
- Groundwater Levels and GIS
- Change in Groundwater Storage

Introduction – Background

Water Plan Update 2013 Groundwater Content Enhancement Work Plan (Scope of Project)

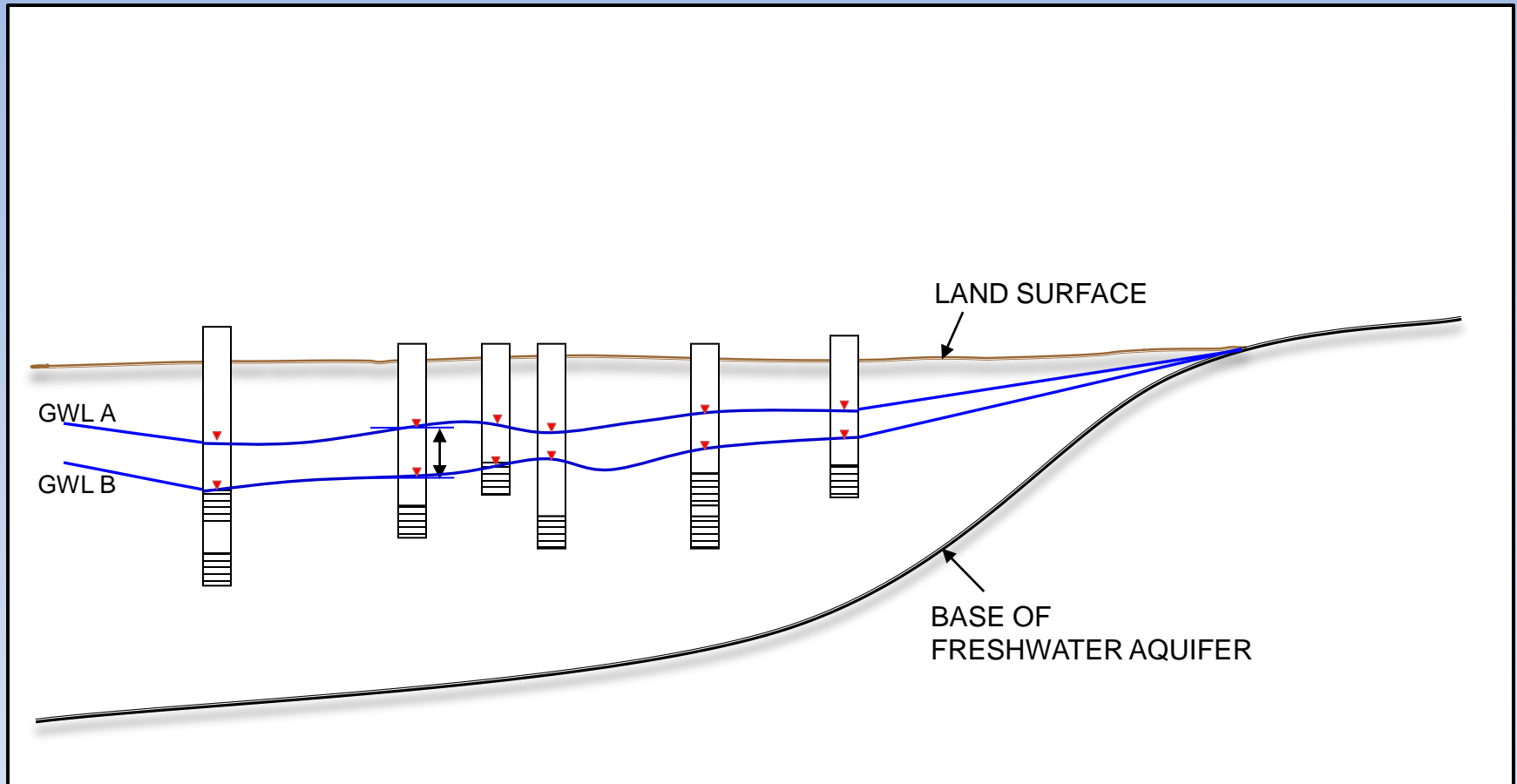
- 1) Compile groundwater information
- 2) Summarize groundwater conditions and management activity
- 3) Identify data gaps
- 4) Estimate annual change in groundwater storage**
- 5) Present Case Studies
- 6) Inventory and describe potential for conjunctive management of groundwater and other supplies
- 7) Inventory and describe potential for groundwater banking and integrated flood management
- 8) Develop preliminary sustainability indicators

Introduction – Background

Task 4 - Goals and Objectives

- Estimate and report annual changes in groundwater storage using groundwater level data
 - Transparent
 - Repeatable
 - A Statewide Process
- Does Not...
 - Replace/supersede other methods
 - Compile or report results from other efforts

Introduction – GW Level Data and GIS



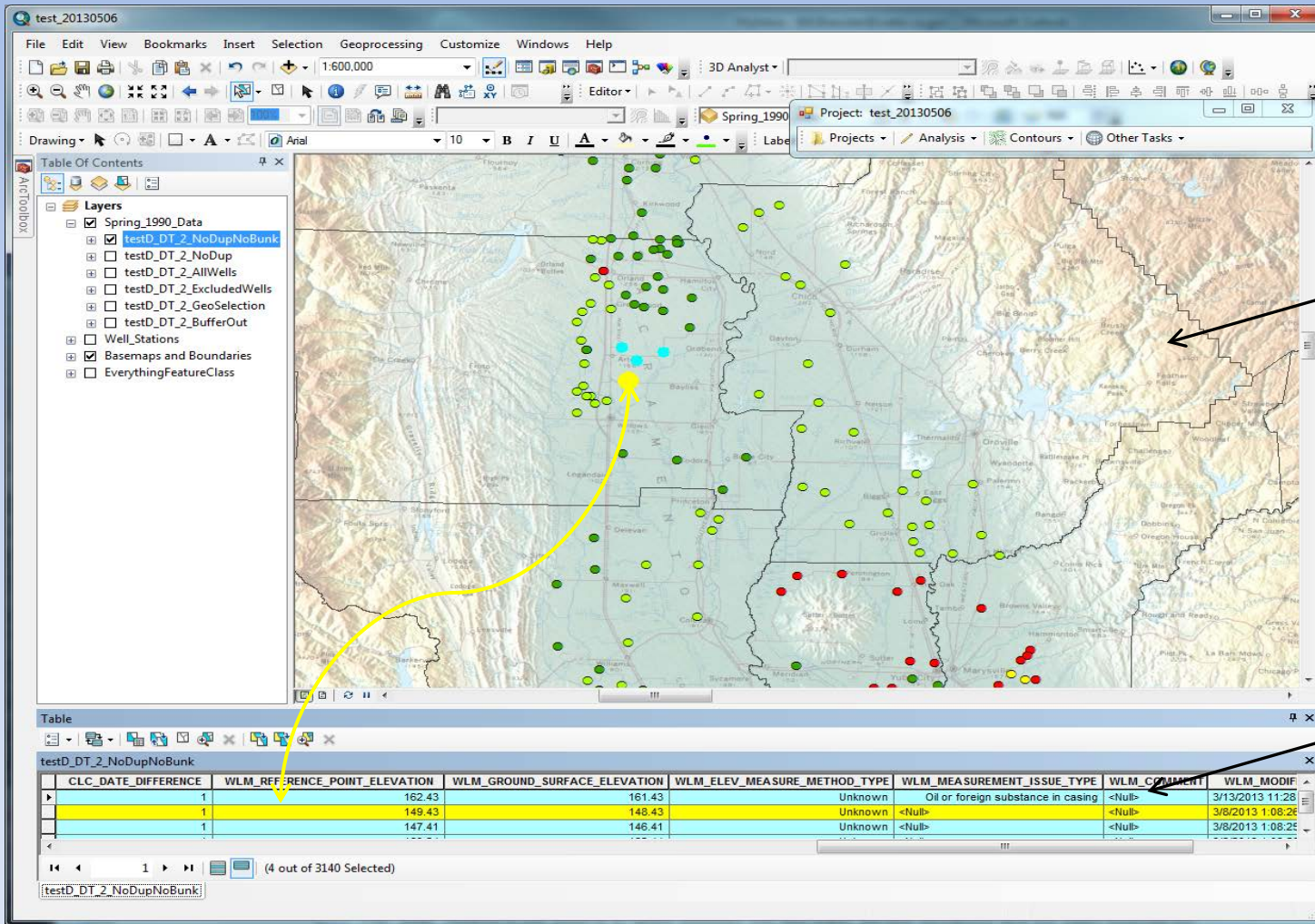
GW level measurement at a single location – provides some information about current conditions

Repeated measurements at a single location – provides information about water level changes

Measurements at multiple locations – provides GWL information for a region

Repeated measurements at multiple locations – provides GWL change information for a region

Introduction – GW Level Data and GIS



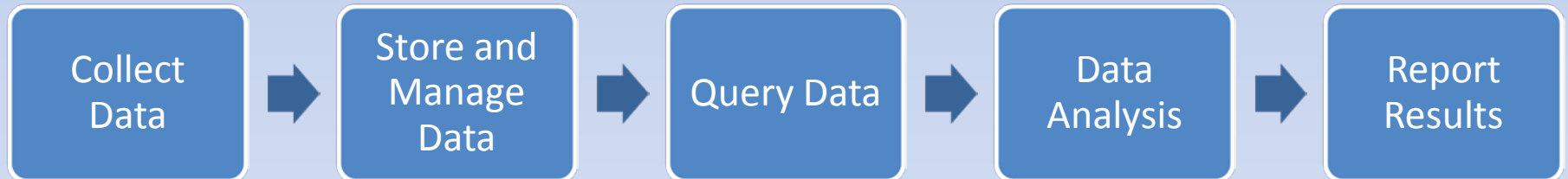
In a map...

and,
in a table.

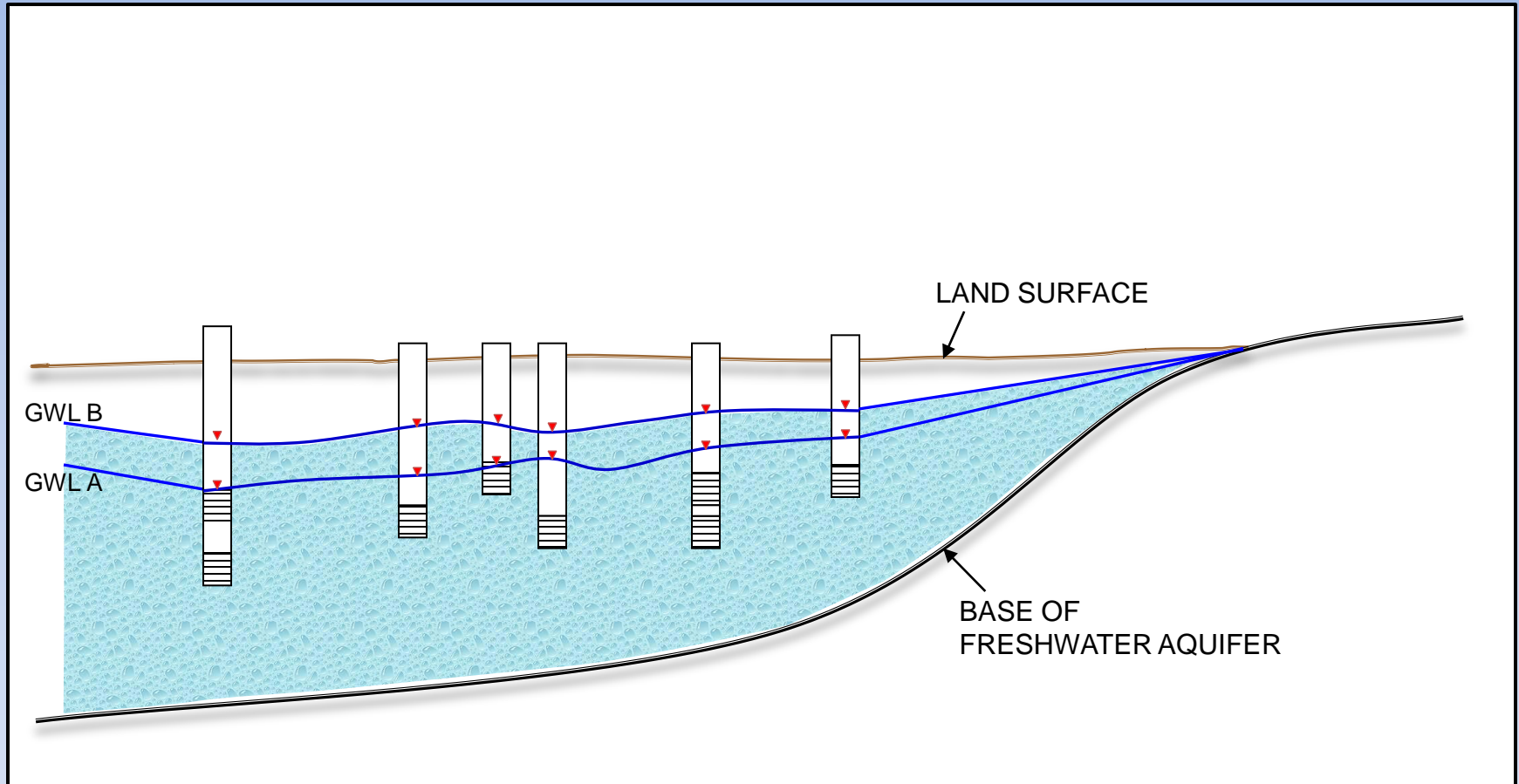
GIS provides a flexible way of looking at the data

Introduction – GW Level Data and GIS

- Using GIS, workflows are used to provide structure to data management and analysis
- Workflows are repeatable, reliable, transparent



Introduction – Change in GW Storage



The change in groundwater storage is the volume described by the difference in groundwater elevation between two monitoring periods, multiplied by the basin area and a storage coefficient (specific yield).

The difference in groundwater elevation is based on measurements collected from wells.



Data Types and Availability

- Well Data
- Groundwater Level Data
- Hydrogeologic Data

Data Types

- Well Data

- Well completion reports (and other well data)
- Quality of information varies

Do Not Fill In
No. 117808

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT

ORIGINAL
Water Corp. No. 13788

(1) OWNER:
Name
Address
City
County
Towns
District

(11) WELL LOG:
Total depth 284 ft. Depth of completed well 284' ft.
Formations Describe by color, character, size of material, and structure
ft. to ft.

(2) TYPE OF WORK (check):
New Well ☒ Drilling ☐ Reconditioning ☐ Destroying ☐
If destruction, describe material and procedure in Item 11.

(3) PROPOSED USE (check):
Domestic ☒ Industrial ☐ Municipal ☐ Other ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:
Rotary ☒
Cable ☐
Other ☐

(6) CASING INSTALLED:
STEEL ☒ OTHER: ☐
SINGLE ☒ DOUBLE ☐
If gravel packed

From ft.	To ft.	Diam.	Gage or Wall	Diameter of Bore	From ft.	To ft.
0	260	3"	Block			

Size of shoe or well rings
Describe notes
Type of perforation or name of screen

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.

(7) PERFORATIONS OR SCREEN:

(8) CONSTRUCTION:
Was a standard regulatory seal provided? Yes ☒ No ☐ To what depth 50' ft.
Were any struts used against pollution? Yes ☐ No ☒ If yes, give depth of struts
From ft. to ft.
To ft. to ft.
Method of sealing

(9) WATER LEVELS:
Depth at which water was first found, if known 15 ft.
Standing level before perforating, if known ft.
Standing level after perforating and developing ft.

(10) WELL TESTS:
Was pump used? Yes ☐ No ☒ If yes, by whom?
Gage: gal./min. with ft. drawdown after hrs. [Signed]
Temperature of water Was a chemical analysis made? Yes ☐ No ☒
Was electric log made of well? Yes ☐ No ☒ If yes, attach copy License

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME
Address

SKETCH LOCATION OF WELL ON REVERSE SIDE

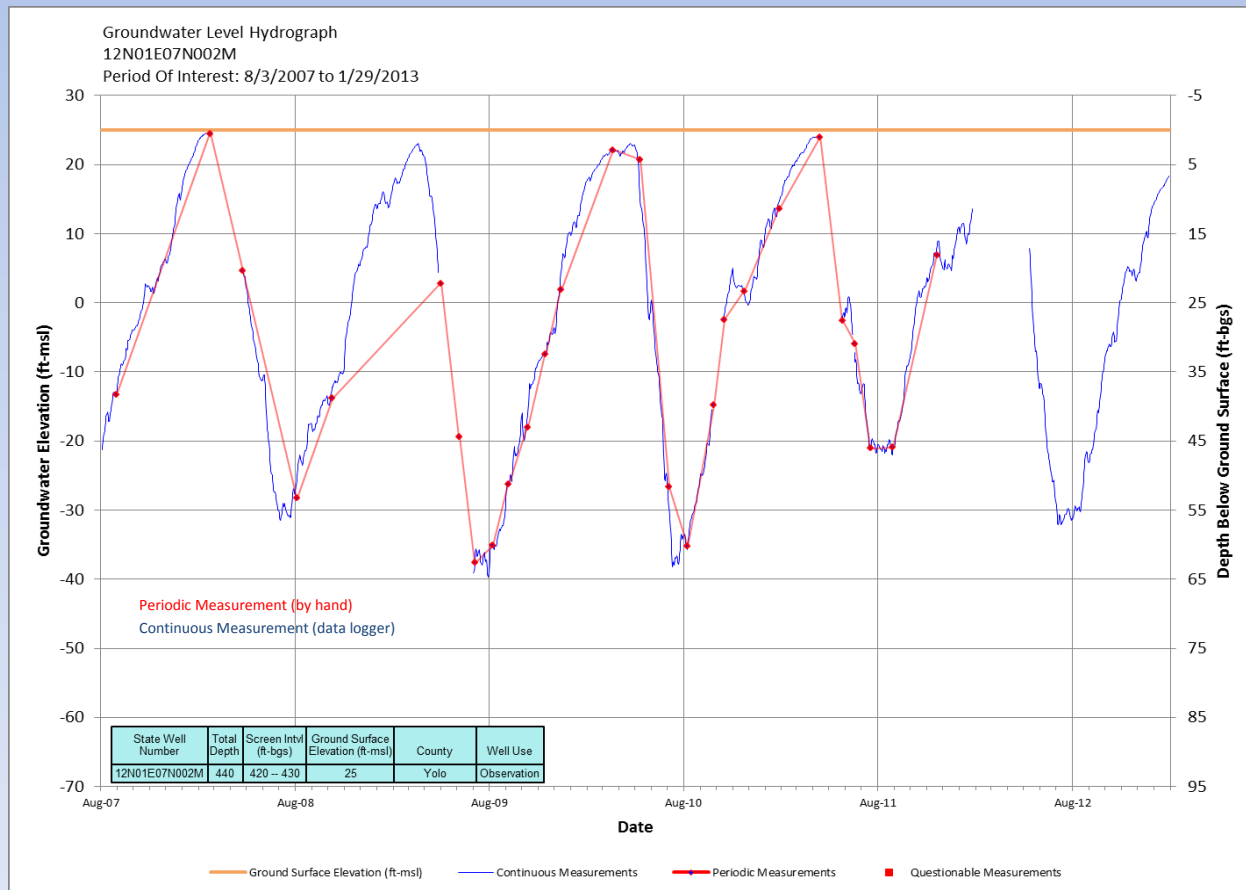
DWR 100 (REV. 9-69)

Data Types

- Groundwater Level Data
 - Collected from wells
 - A groundwater measurement records:
 - A point in space (x, y, z)
 - A point in time
 - Metadata about the measurement
 - Data collected from multiple wells show changes over an area
 - Repeated measurements show changes in time

Data Types

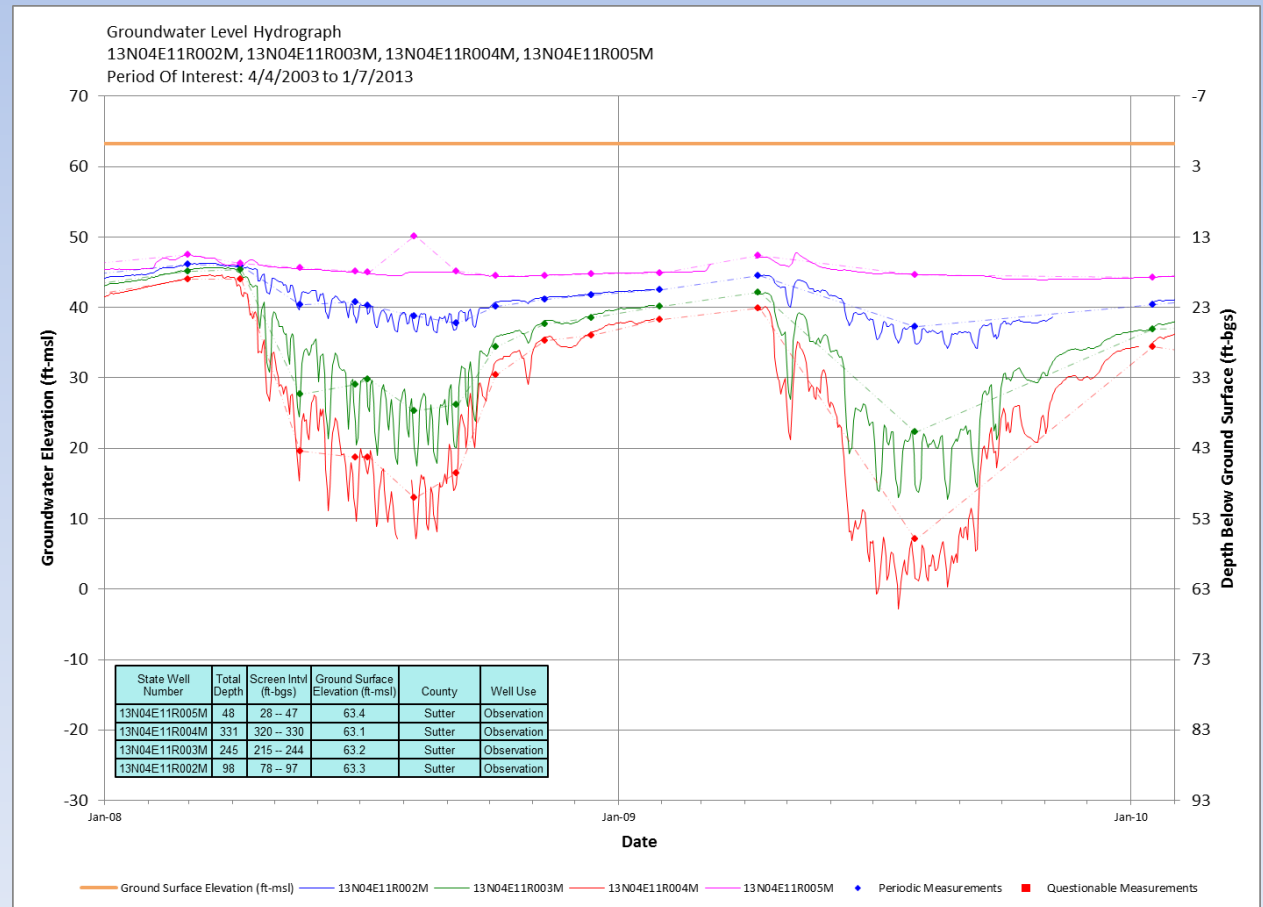
- Groundwater Level Data
 - Hydrograph...groundwater levels over time



Ground Surface

Data Types

- Groundwater Level Data
 - Multi-completion well



Data Types

- Hydrogeologic Data

- Aquifer Properties

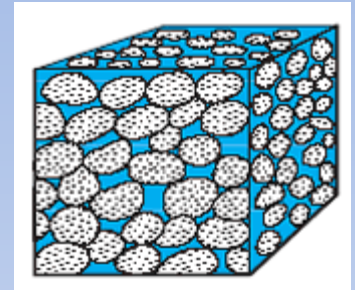
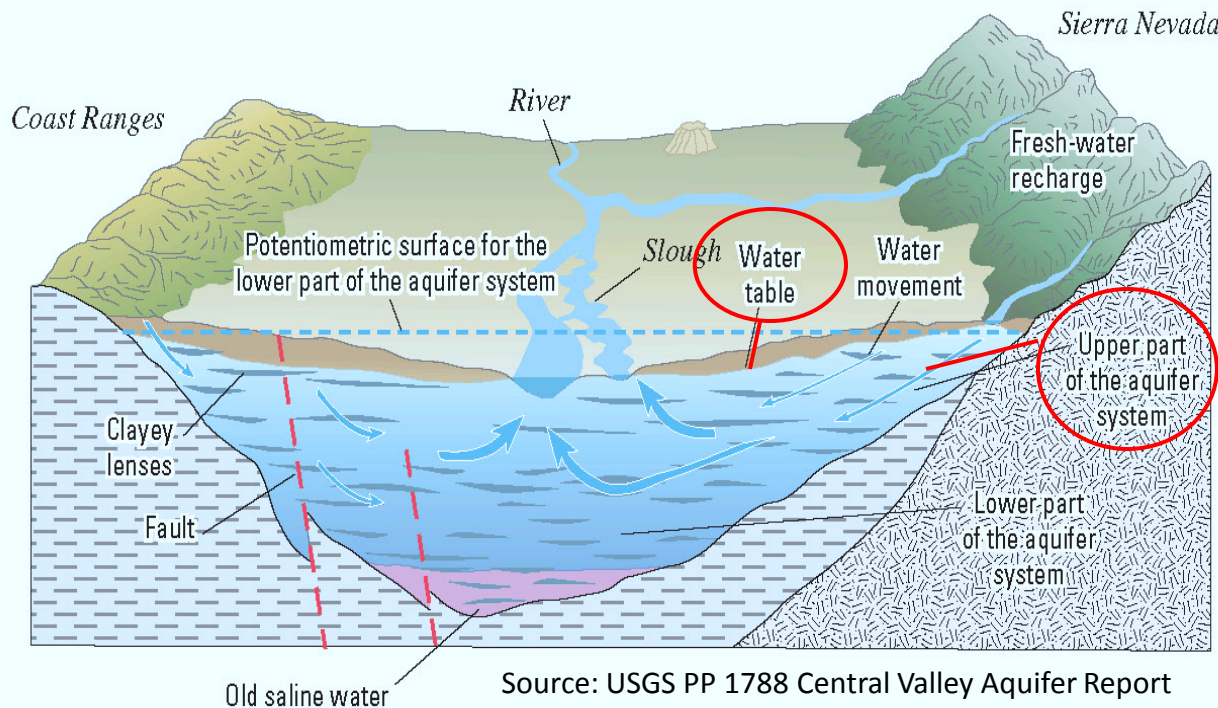
- An unconfined groundwater system is assumed

- Storage Coefficients

- Specific Yield (S_y) is used in unconfined GW systems**

- Specific Storage (S_s) is used in confined GW systems

Aquifer Properties and Storage Coefficients



Water stored between the individual grains of sand & gravel



Average Specific Yield Values

(Applied Hydrology, C.W. Fetter)

Material / Texture	Average S_y Value
Clay	0.02
Sandy Clay	0.07
Silt	0.18
Coarse Sand	0.27
Coarse Gravel	0.22

Data Availability

- Well Data
 - Abundant, but the quality is highly variable
- Water Level Data
 - Generally abundant, highly variable in time and location
- Hydrogeologic Data
 - Not consistent, detailed in some areas



Examples of Other Methods...

- DWR C2VSIM (2013)
 - *California Central Valley Groundwater-Surface Water Simulation Model*
 - <http://ca.water.usgs.gov/projects/central-valley/central-valley-hydrologic-model.html>
- USGS CVHM (2009)
 - *Central Valley Hydrologic Model*
 - http://pubs.usgs.gov/pp/1766/PP_1766.pdf
- NASA GRACE
 - *The Gravity Recovery and Climate Experiment*
 - <http://science1.nasa.gov/missions/grace/>
- USGS Scientific Investigations Report 2012-5291 (2013)
 - *Water-level and storage changes in the High Plains aquifer, predevelopment to 2011 and 2009-11*
 - <http://pubs.usgs.gov/sir/2012/5291/>



Estimating Change in GW Storage – Task 4 Methodology

- Part 1: Synopsis, Goals, Assumptions, Key Concepts (25 min)
- Q&A (10 min)

----- BREAK -----

- Part 2: Workflow Process (60 min)
- Q&A (10 min)

Task 4 Methodology

- Synopsis
 - New methods to analyze and report GWL data
- Goals
 - Transparent, Repeatable, Reliable
 - Create Standardized Reports
- Assumptions and Key Concepts
 - Eight Assumptions
 - Seven Key Concepts

Task 4 Methodology - Assumptions

1. All data must reside in the DWR Water Data Library*
 - ✓ Queries are run against a single database
 - ✓ Repeatable, reliable, transparent
2. Initially, all groundwater level data is considered appropriate, high quality data, and is filtered or otherwise removed as needed during the process “workflow”
 - ✓ Wells are not pre-selected based on selection criteria
 - ✓ QA/QC of data is built into the “workflow”

Task 4 Methodology – Assumption 2 (wells are not preselected)

SELECTION CRITERIA	WELL COUNT
Number of wells in the database	39,995
wells that have depth and screen information	3,989
...and Well Completion Reports	2,484
And were measured	
...between 2005 and 2010	893
...in spring	824
...of 2010 only	719
And are located in the Central Valley	419
... With perforations in the unconfined aquifer	296
... And are dedicated Observation wells	89

If there are so many wells, why don't we just pick the ones we want to use ahead of time?

Spring 2010

Task 4 Methodology – Assumption 2

Why not preselect wells?

- Preselecting based on “one size fits all” criteria eliminates useable data
- Well data is formally reviewed through QA/QC measures built into the workflow

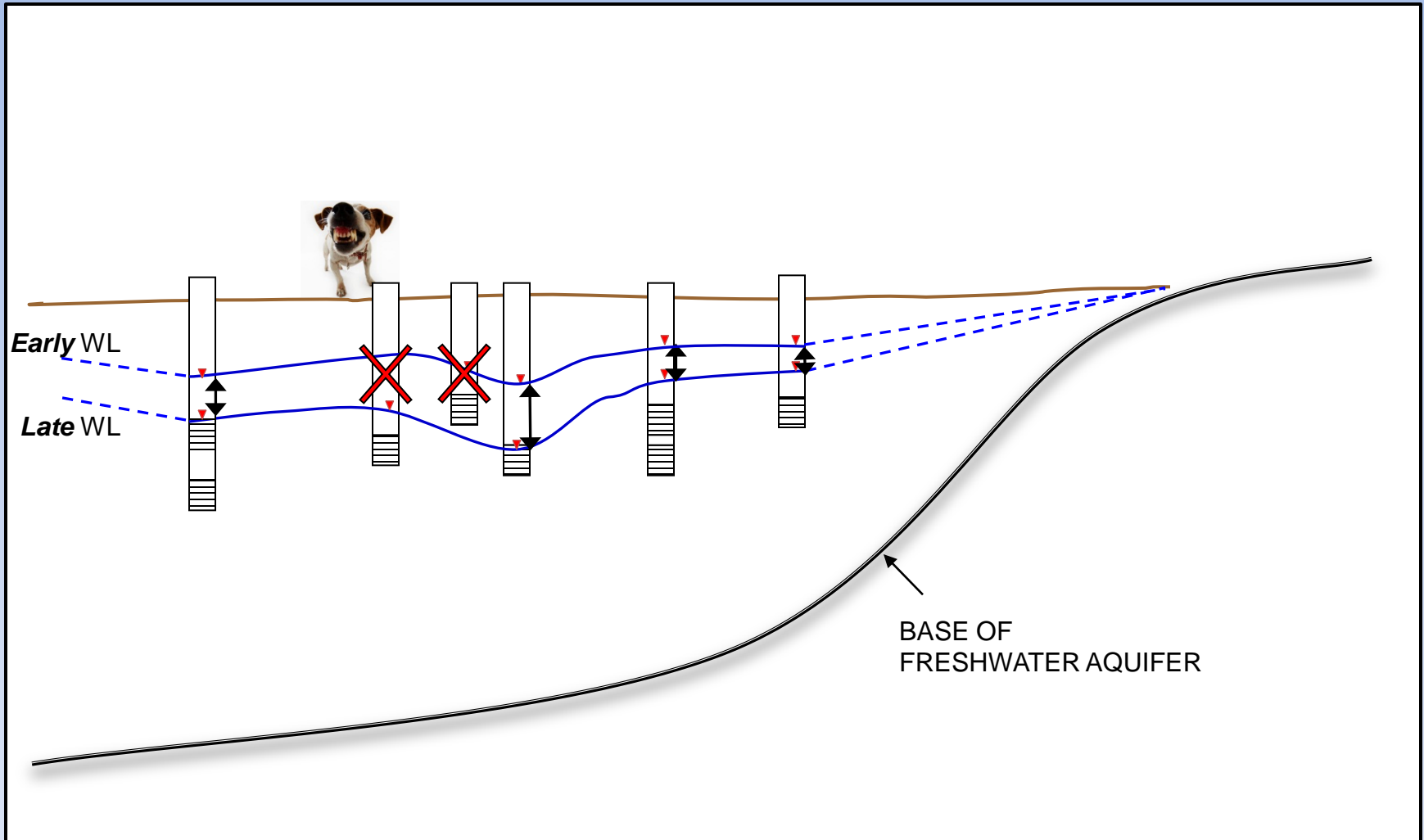
These are the spring 2010 measurements used without preselecting wells (over 3000)

Task 4 Methodology - Assumptions

(continued)

3. Groundwater levels represent unconfined, static, aquifer conditions
4. Only “spring to spring” changes in groundwater storage are estimated
 - ✓ NOTE: Water levels are collected just prior to the first irrigation of the year, which can range from January to May, depending on the region and year
5. Groundwater level change is calculated from two water level measurements in the same well**

Task 4 Methodology - Assumptions



Groundwater level change is calculated from two water level measurements in the same well

Task 4 Methodology - Assumptions

(continued)

6. The extent, or geographic limit, of the groundwater basin is delineated and it is assumed that no changes in groundwater elevations occur at this boundary
7. The extent, or geographic limit, of available groundwater level data is delineated
8. Specific Yield values are applied as an average for an entire Reporting Area**

Task 4 Methodology - Assumptions

8) Specific Yield

- Specific Yield (S_y) is used in unconfined systems
- Historically $S_y=0.07$ was used *
- Recent models have higher S_y values
 - CVHM: S_y is around 0.17 (mean)
 - C2VSIM: S_y is around 0.19 (mean)
- CWP Update 2013 Deliverable 4 provides a range:
 - Min $S_y= 0.07$
 - Max $S_y= 0.17$
- Other values may be used as more is understood

* see Williams and others (1989) and DWR B118-6, 1978 Appendix A for more details

Task 4 Methodology - Assumptions

1. All data must reside in the DWR Water Data Library*
2. Initially, all groundwater level data is considered appropriate, high quality, data and is filtered or otherwise removed as needed during the process workflow
3. Groundwater levels represent unconfined, static, aquifer conditions
4. Only “spring to spring” changes in groundwater storage are estimated
5. Groundwater level change is calculated from two water level measurements in the same well**
6. The groundwater basin boundary (geographic extent) is delineated and it is assumed that no changes in groundwater elevations occur at this boundary. This is the “zero” boundary.
7. The extent, or geographic limit, of available groundwater level data is delineated
8. Specific Yield values are applied as an average for an entire Reporting Area**

*As of 2011 groundwater level data is maintained as part of the CASGEM database

**DWR is currently revising and updating this process

Task 4 Methodology – Key Concepts

1) Groundwater Basin Boundaries

- A groundwater basin is defined as an alluvial aquifer with reasonably well-defined boundaries in a lateral direction and a definable bottom
- Groundwater levels do not change at the basin edge

2) Reporting Areas and Non-Reporting Areas

- *Reporting areas* are areas of interest where change in groundwater storage is estimated and reported
- Areas of interest where it is not possible to estimate change in groundwater storage are *Non-Reporting Areas*
 - Outside of a GW basin
 - Lacks sufficient data

Task 4 Methodology – Key Concepts

(continued)

3) Depth to groundwater and groundwater elevation

- Depth to groundwater or depth below ground surface (DBGS) is a measurement
- Water surface elevation (WSEL) is calculated from the DGBS and ground surface elevation

$$\text{WSEL} = \text{ground surface elevation} - \text{DBGS}$$

4) Selecting unique groundwater level measurements

- A unique measurement is a single GW level measurement for a given well within a given time period
- Selection is based on a variety of filtering criteria

Task 4 Methodology – Key Concepts

(continued)

5) Groundwater level surfaces (WSEL and DBGS)

- A computer generated representation of the groundwater table based on measurements from wells
- In GIS the WSEL surface and the DBGS surface are the same, but use different reference points

6) Change in groundwater level

- The difference in groundwater elevation calculated from two measurements collected from a given well

7) Change in groundwater storage

- the volume described by the difference in groundwater elevation between two monitoring periods, multiplied by the basin area and storage coefficient (specific yield)

Task 4 Methodology – Key Concepts

- 1) Groundwater Basin and Subbasin Boundaries
- 2) Reporting Areas and Non-Reporting Areas
- 3) Depth to groundwater and groundwater elevation
- 4) Selecting unique groundwater level measurements
- 5) Groundwater level surfaces (WSEL and DBGS)
- 6) Change in groundwater level
- 7) Change in groundwater storage

QUESTIONS?



Task 4 Methodology

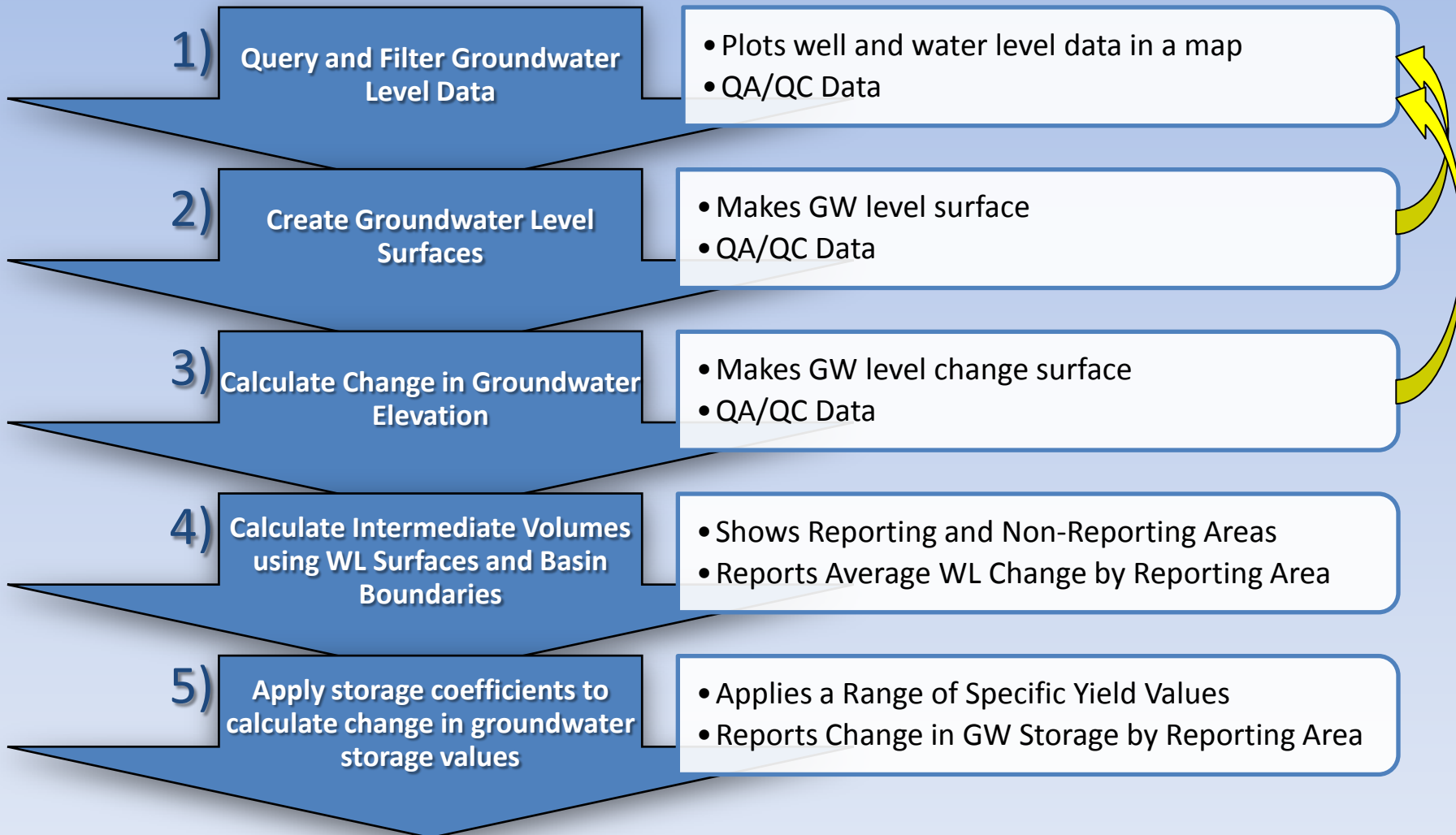
Workflow Process

First things first...

- Workflow = a sequence of connected steps
 - Implemented using custom GIS tools
- Data collection and data management in WDL is important (but not discussed here)
- Prior to running GIS tools, WL data is transferred from the WDL Oracle database to a Geodatabase using an automated process

Task 4 Methodology

Workflow Process



Task 4 Methodology

Workflow Process

1) Query and Filter Groundwater Level Data for “Spring” Datasets

- Filters data by:
 - » Geographic location
 - » Date range and target date
 - » Well construction parameters
 - » Water level measurement metadata (QM codes)
 - » Well exclusion information
- Plots well and water level data in a map
- Allows for data QA/QC

Relates to:

Assumption 1 – Data must be in WDL

Assumption 2 – Begin with all available data

Key Concept 4 – Unique GWL measurement

Task 4 Methodology

Workflow Process

1) Query and filter Groundwater level data for “spring” datasets

DESCRIPTION OF INPUT PARAMETERS

Parameter	Data Description	Purpose
Geographic Region	Polygon feature	Limits the geographic scope of the query
Date Range	Minimum date value and maximum date value	Selects well measurement data within a specific date range
Target Date	Date	Selects the water level measurement nearest the specified target date. Provides UNIQUE measurement for each well.
Well Depth	Depth, in feet	Filters wells by depth
Custom Query	SQL Script	Provides flexibility to the user. Allows the user to modify filters
Questionable Measurement Code	Coded values (alphanumeric)	Filters out measurements with specific measurement quality codes (such as “well is pumping” or “pumping well nearby”)
Excluded Wells	Table of wells and associated codes	Removes wells that are listed on the Excluded Wells table

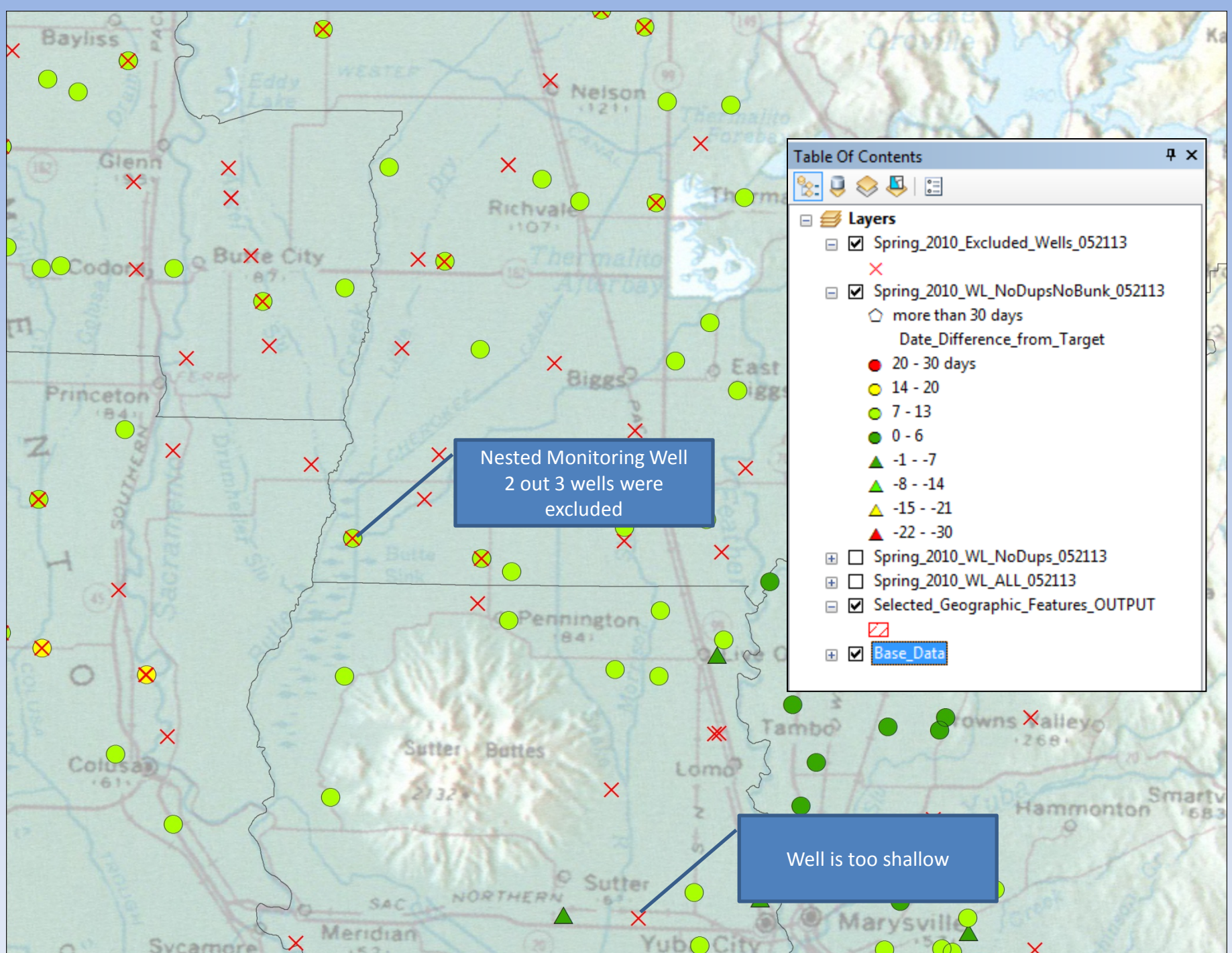


Table Of Contents

- ☒ Layers
 - ☒ Spring_2010_Excluded_Wells_052113
 - X
 - ☒ Spring_2010_WL_NoDupsNoBunk_052113
 - more than 30 days
 - Date_Difference_from_Target
 - 20 - 30 days
 - 14 - 20
 - 7 - 13
 - 0 - 6
 - 1 - -7
 - 8 - -14
 - 15 - -21
 - 22 - -30
 - ☐ Spring_2010_WL_NoDups_052113
 - ☐ Spring_2010_WL_ALL_052113
 - ☒ Selected_Geographic_Features_OUTPUT
 - ☒ Base_Data

Task 4 Methodology

Workflow Process

- 2) Create groundwater level surfaces within defined basins
 - Uses filtered point data from Step One
 - Creates triangulated irregular network (TIN) and TIN contours
 - Can build WSEL and/or DBGS surfaces
 - Allows for data QA/QC

Relates to:

Assumption 3 – GWL's represent unconfined conditions

Key Concept 5 – Groundwater level surfaces

Task 4 Methodology

Workflow Process

2) Create groundwater level surfaces within defined basins

DESCRIPTION OF INPUT PARAMETERS

Parameter	Data Description	Purpose
Water Level Data	Point Feature – filtered, with one point per well site	Source data
Custom SQL Statement (optional)	SQL Script	Provides flexibility to the user. Allows the user to modify point input.
Contour Interval	Number (ft)	Contour interval
Maximum Tin Edge Length	Describes the maximum allowed distance between to points used to create the TIN	Forces the TIN to conform to the point data better
Output TIN file name Output Contour file name	String	Names for the output files

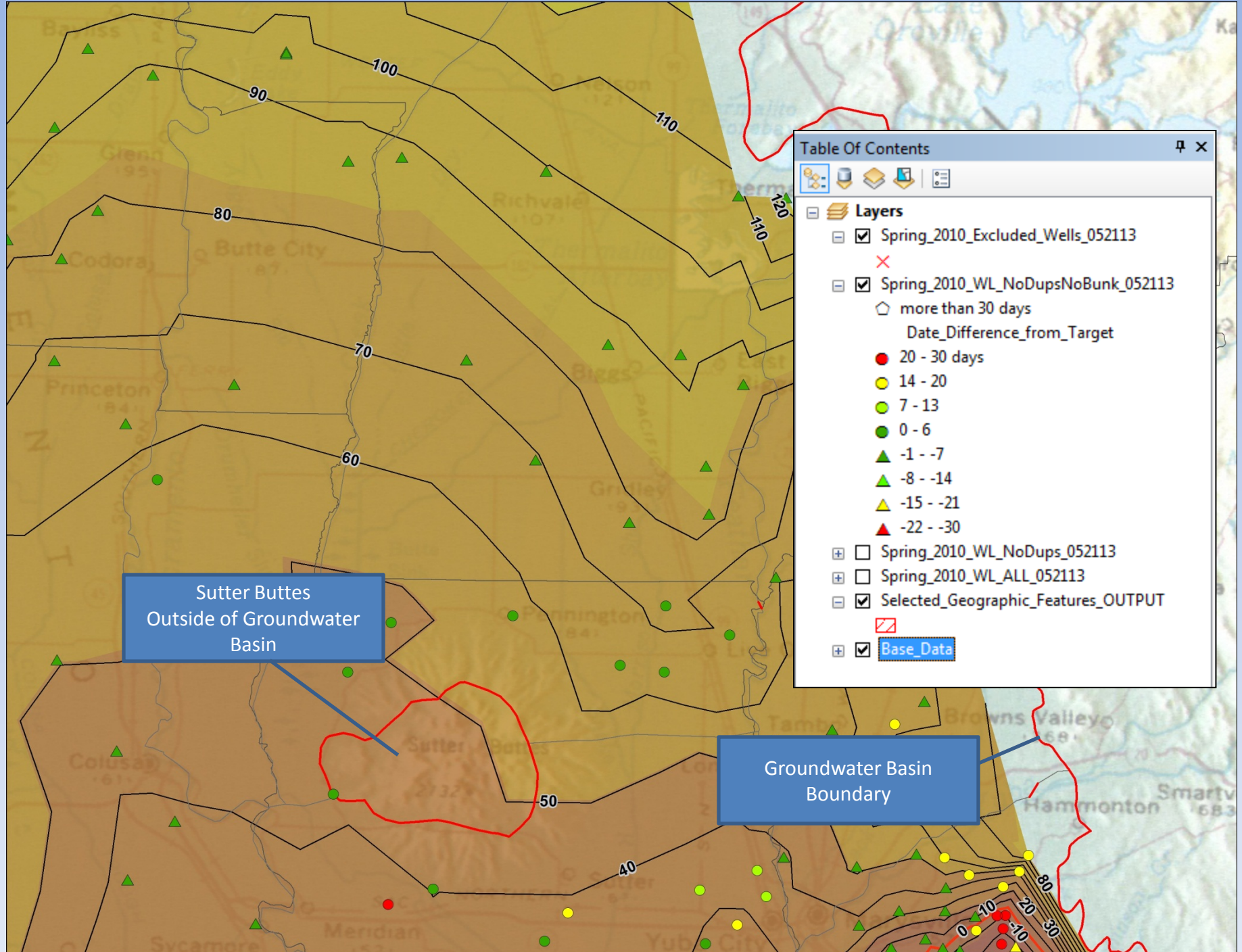
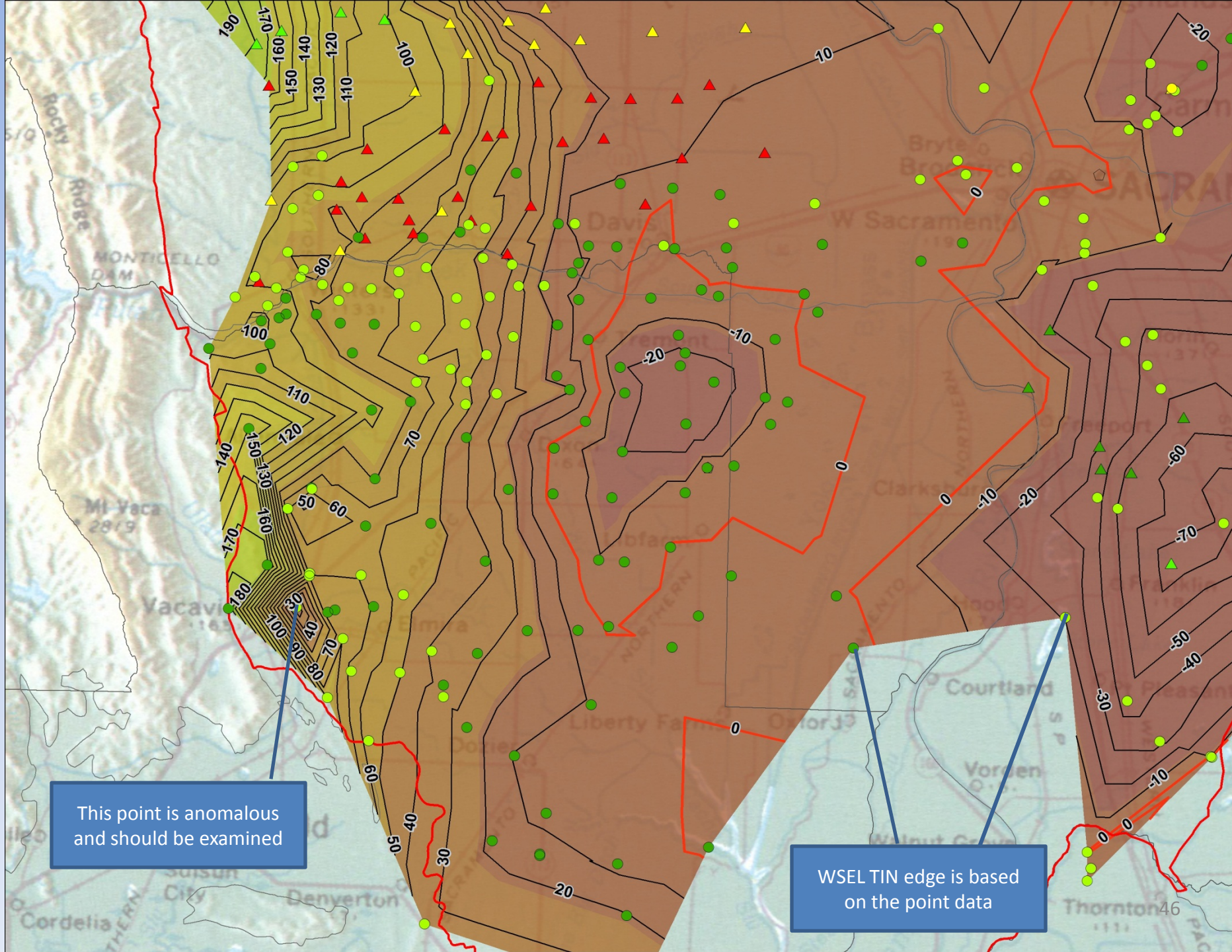


Table Of Contents	
Layers	
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<input checked="" type="checkbox"/>	Spring_2010_WL_NoDupsNoBunk_052113
	more than 30 days
	Date_Difference_from_Target
	20 - 30 days
	14 - 20
	7 - 13
	0 - 6
	-1 - -7
	-8 - -14
	-15 - -21
	-22 - -30
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<input type="checkbox"/>	Spring_2010_WL_ALL_052113
<input checked="" type="checkbox"/>	Selected_Geographic_Features_OUTPUT
<input checked="" type="checkbox"/>	Base_Data



This point is anomalous and should be examined

WSEL TIN edge is based on the point data

Task 4 Methodology

Workflow Process

- 3) Calculate change in groundwater elevation over time
 - Makes GW level change surface
 - » From “early” and “late” time periods
 - Uses data from wells with measurements in both time periods
 - Allows data QA/QC

Relates to:

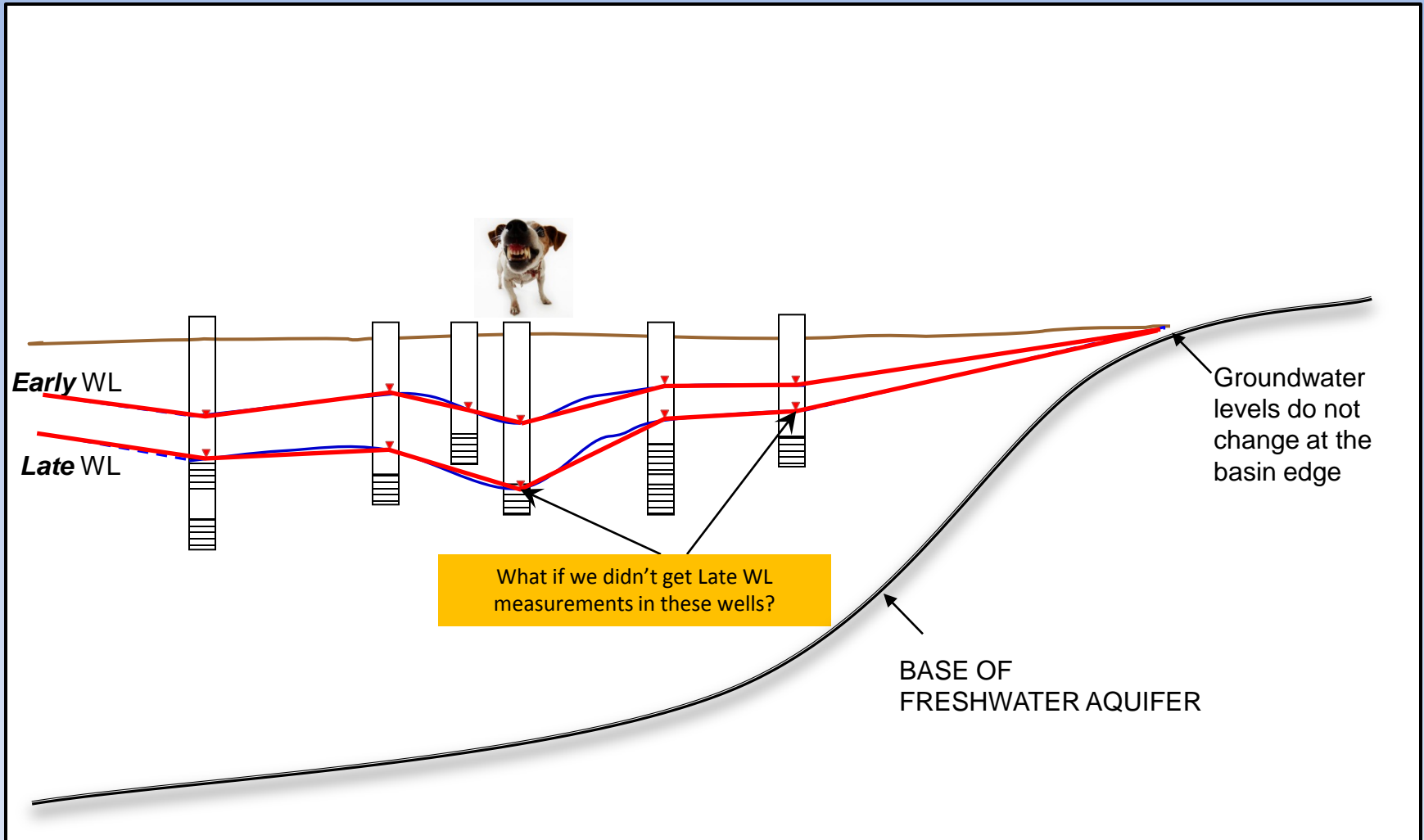
Assumption 4 – Only “spring” to “spring” change is used

Assumption 5 – GW level change is calculated from wells with measurements in both time periods

Key Concept 6 – Change in GW level

Task 4 Methodology - Workflow Process

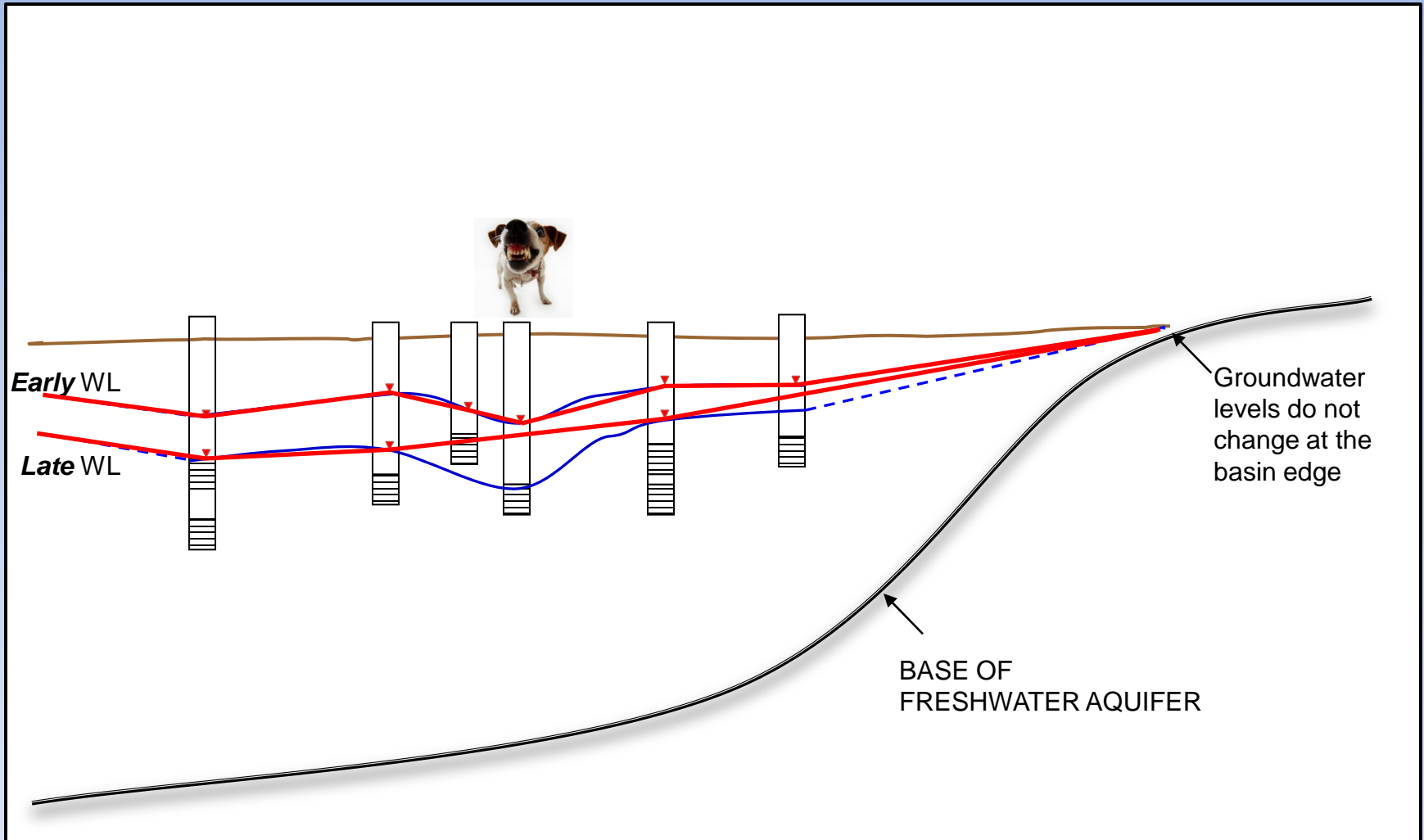
STEP THREE – CALCULATE CHANGE IN GROUNDWATER ELEVATION OVER TIME



Groundwater level change is calculated from two water level measurements in the same well

Task 4 Methodology - Workflow Process

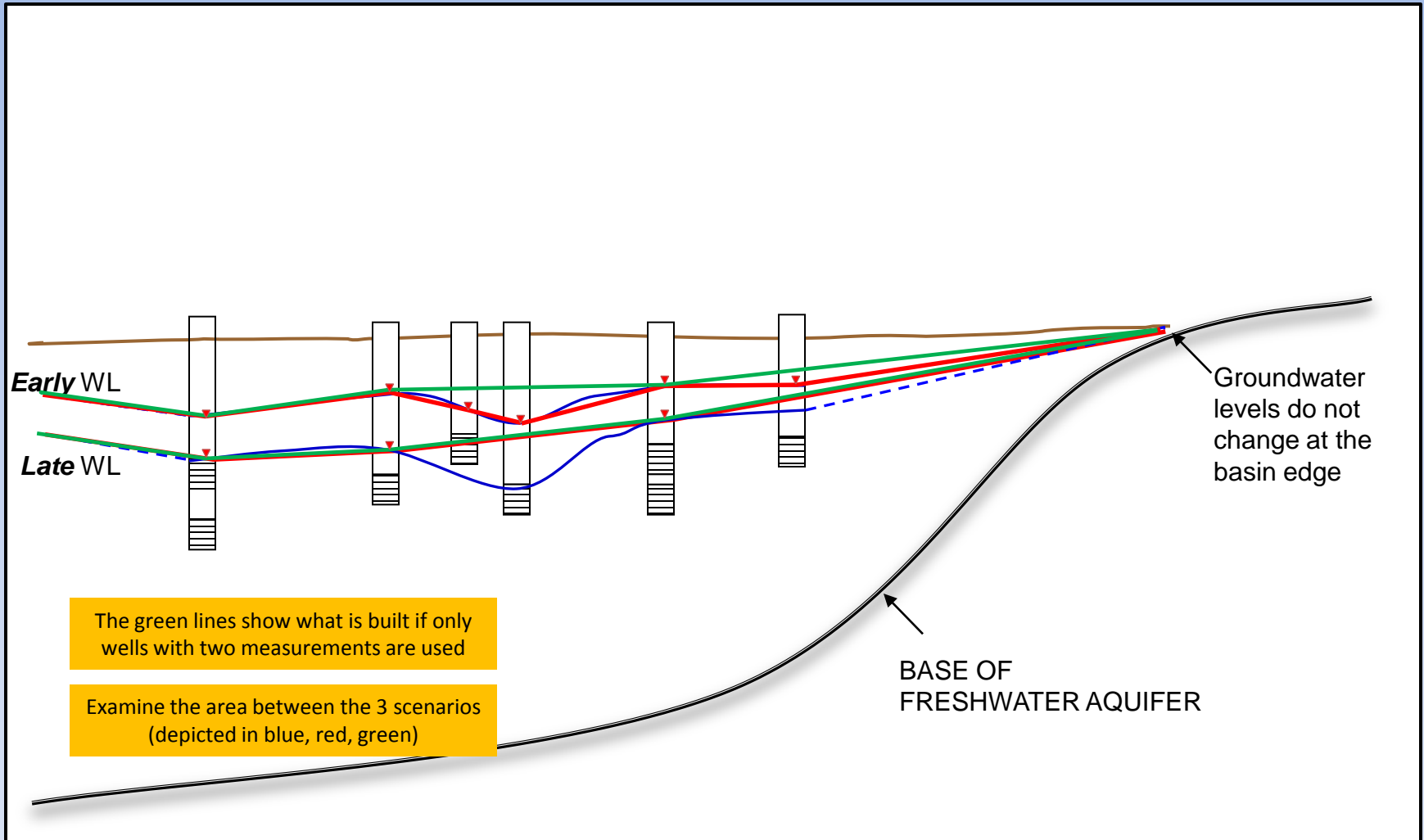
STEP THREE – CALCULATE CHANGE IN GROUNDWATER ELEVATION OVER TIME



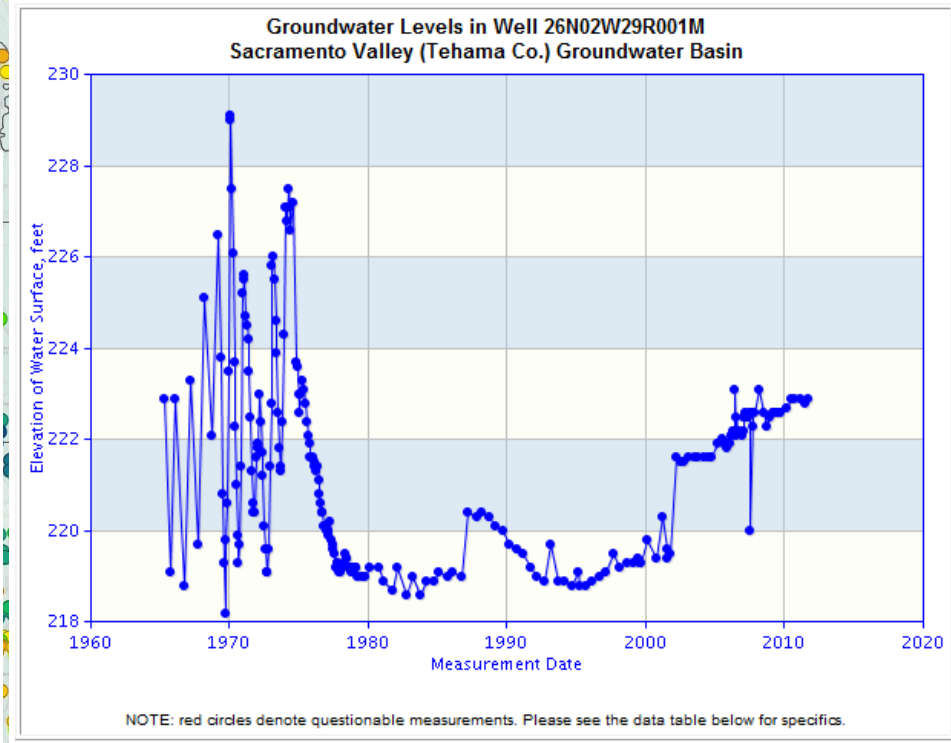
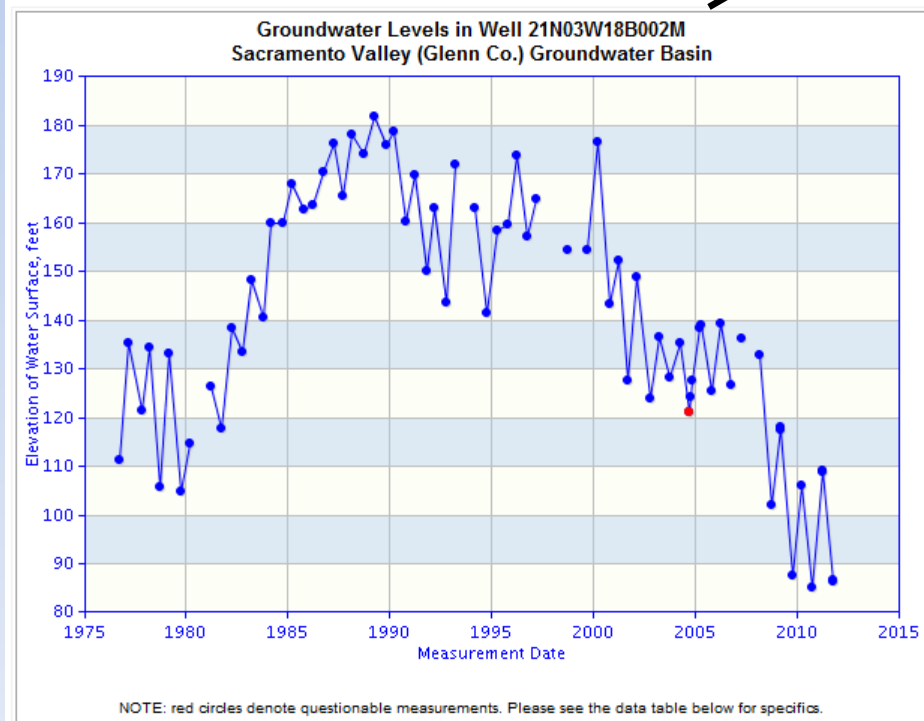
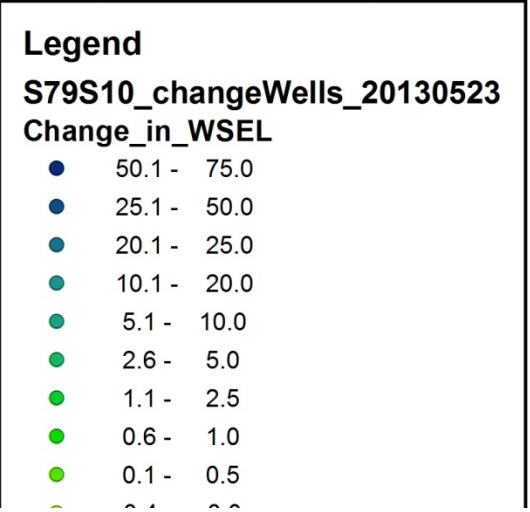
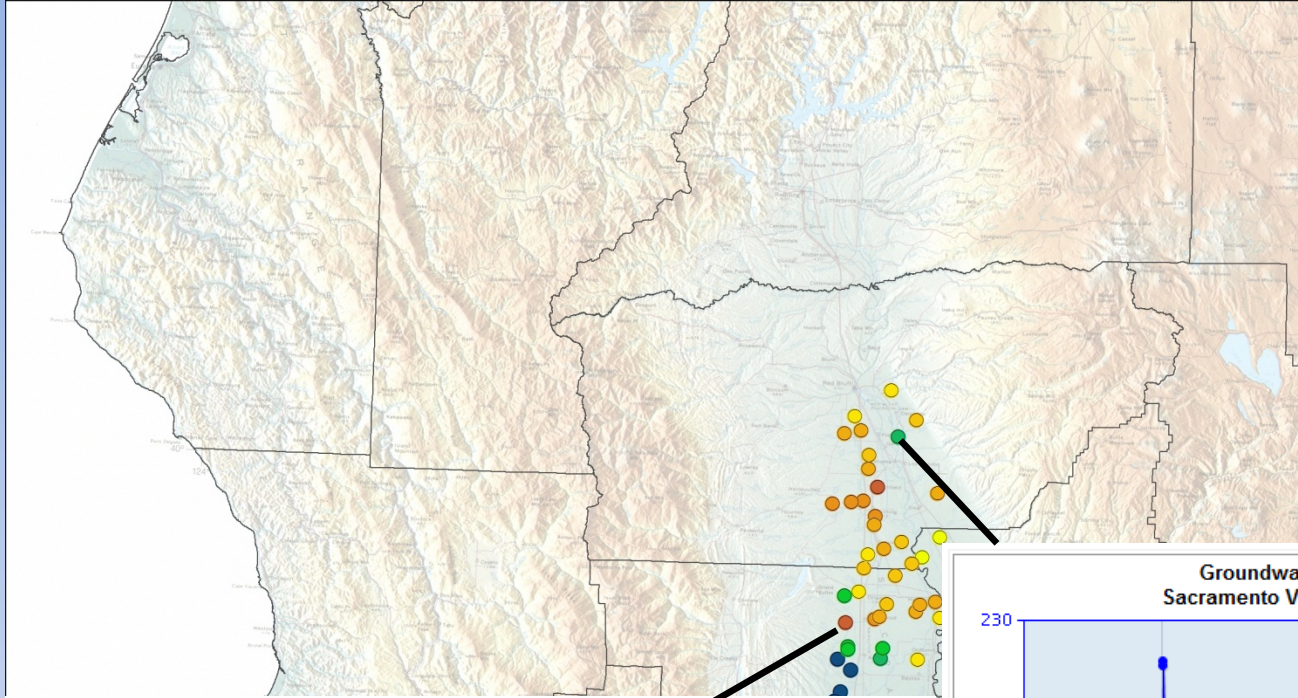
Groundwater level change is calculated from two water level measurements in the same well

Task 4 Methodology - Workflow Process

STEP THREE – CALCULATE CHANGE IN GROUNDWATER ELEVATION OVER TIME



Groundwater level change is calculated from two water level measurements in the same well



Task 4 Methodology

Workflow Process

- 4) Calculate intermediate volumes using change points and basin boundaries
 - Creates a Change Surface from Change Points and a Zero Boundary
 - Shows Reporting and Non-Reporting Areas
 - Reports Average WL Change by Reporting Area

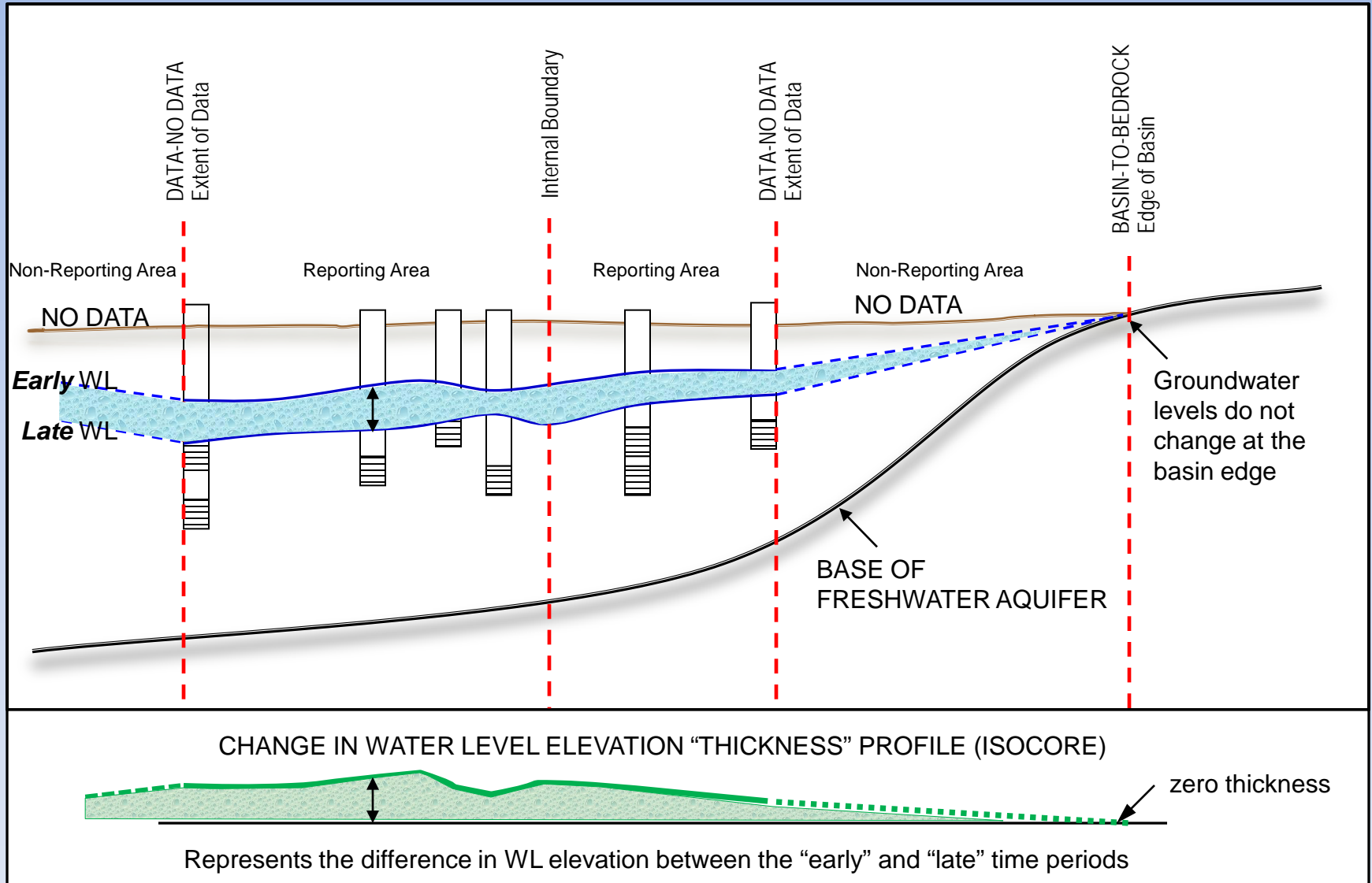
Relates to:

Assumption 6 – The extent of the GW basin is delineated (zero boundary)

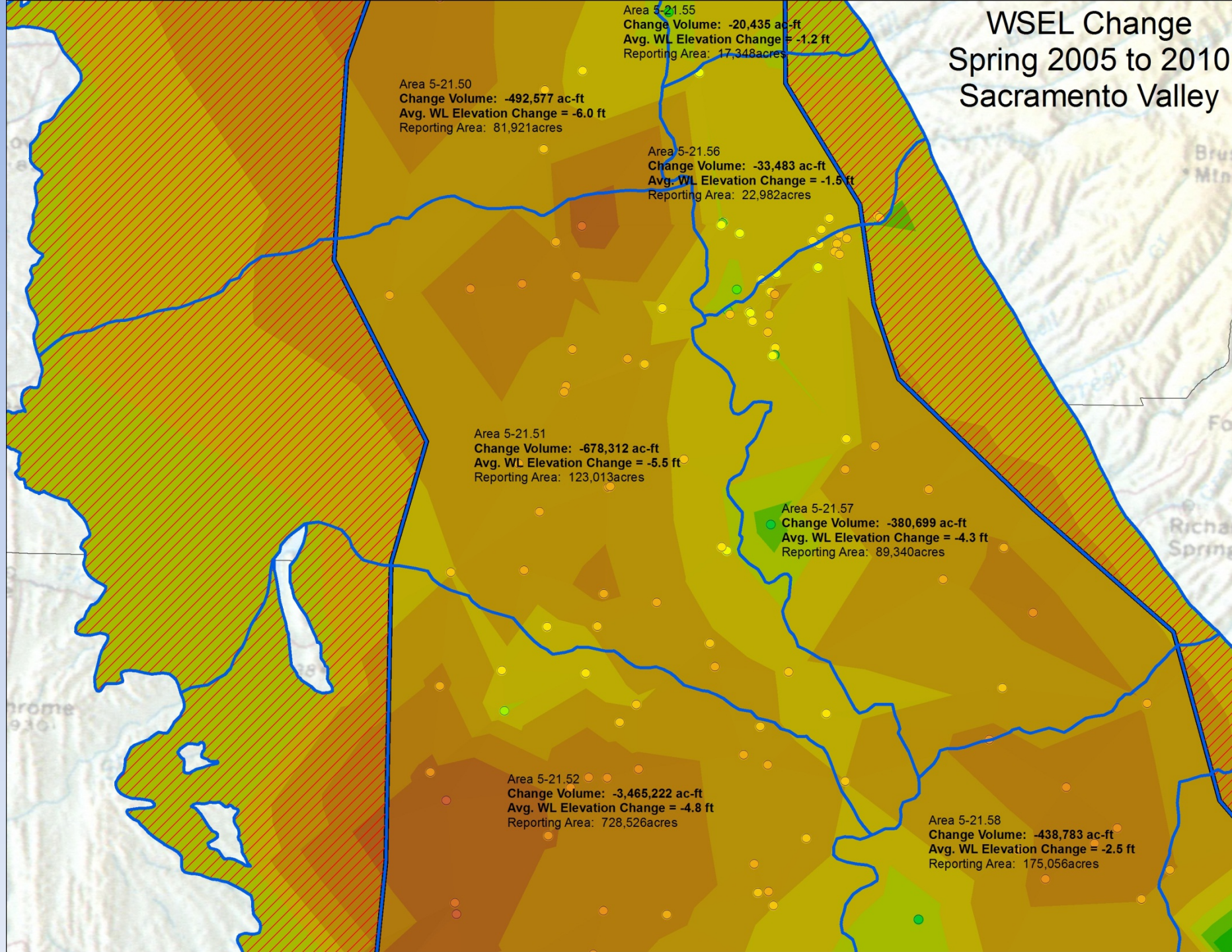
Assumption 7 – The extent of available data is delineated

Task 4 Methodology - Workflow Process

STEP FOUR – CALCULATE INTERMEDIATE VOLUME



WSEL Change Spring 2005 to 2010 Sacramento Valley



Task 4 Methodology

Workflow Process

- 5) Apply storage coefficients to calculate change in groundwater storage values
- Applies a Range of Specific Yield Values
 - Reports Change in GW Storage by Reporting Area
 - Results presented in tables and charts

Relates to:

Assumption 3 – Unconfined aquifer conditions

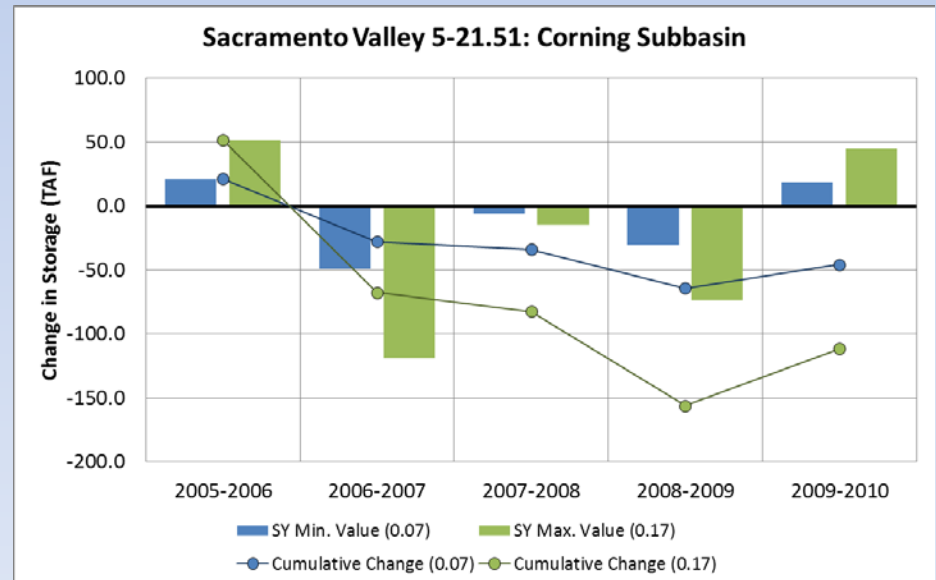
Assumption 7 – Specific yield values are applied as an average for each reporting area

Task 4 Methodology - Workflow Process

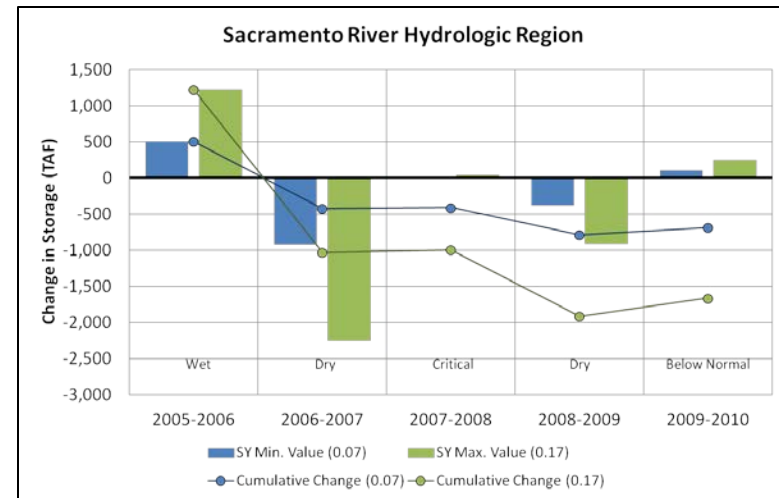
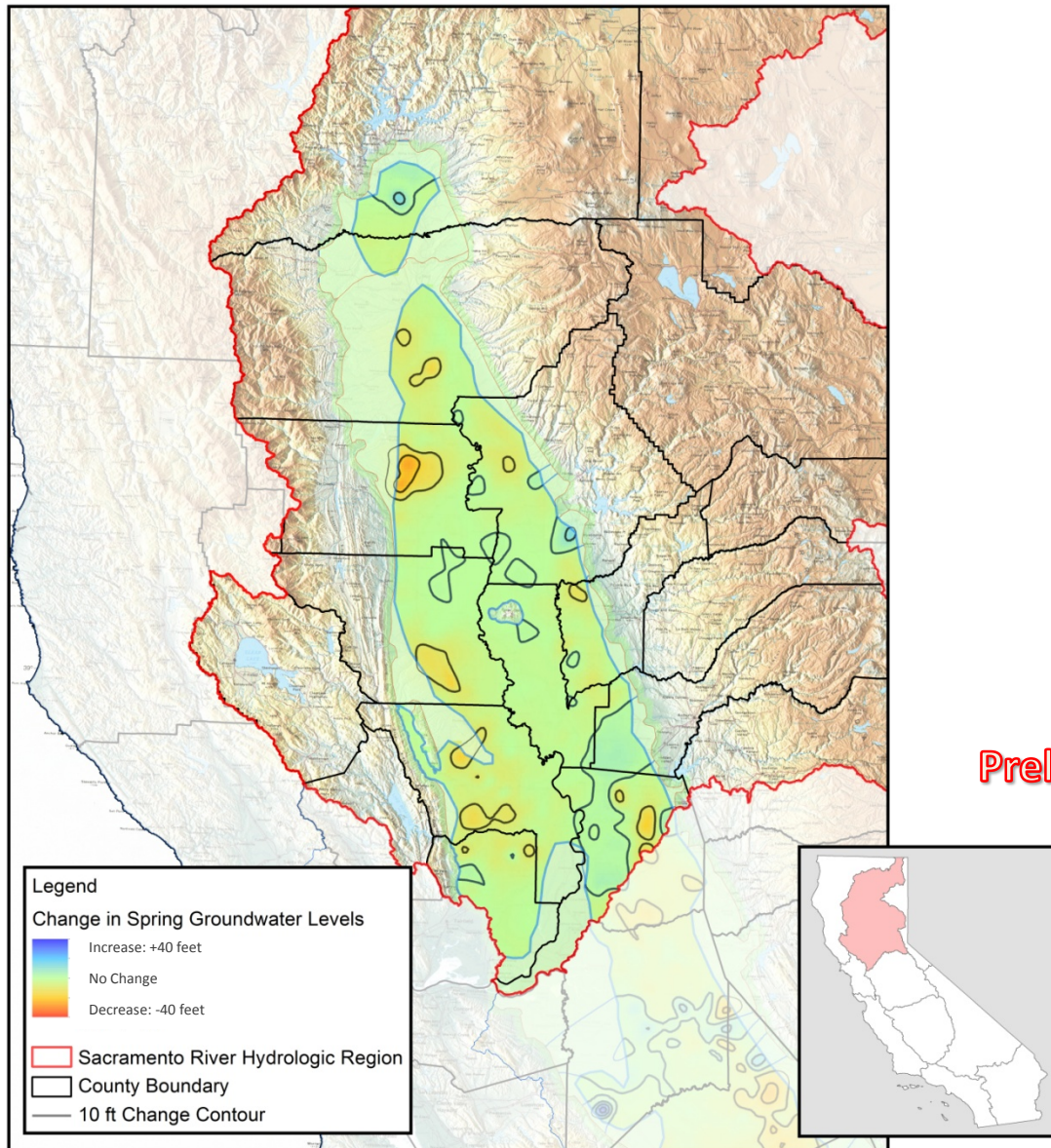
STEP FIVE – APPLY STORAGE COEFFICIENT

Sacramento Valley 5-21.51: Corning Subbasin			
Reporting Area (Acres): 123,013			
Non-Reporting Area (Acres): 82,606			
Period Spring - Spring	Average Change in GW Elevation (feet)	Estimated Change in Storage in TAF	
		Assuming Specific Yield = 0.07	Assuming Specific Yield = 0.17
2005-2006	2.5	21.2	51.4
2006-2007	-5.7	-49.1	-119.2
2007-2008	-0.7	-6.1	-14.9
2008-2009	-3.5	-30.3	-73.5
2009-2010	2.1	18.4	44.6
2005-2010 (total)	-5.3	-46.0	-111.6

Note: GW elevation and change in storage estimates are calculated within reporting area only.

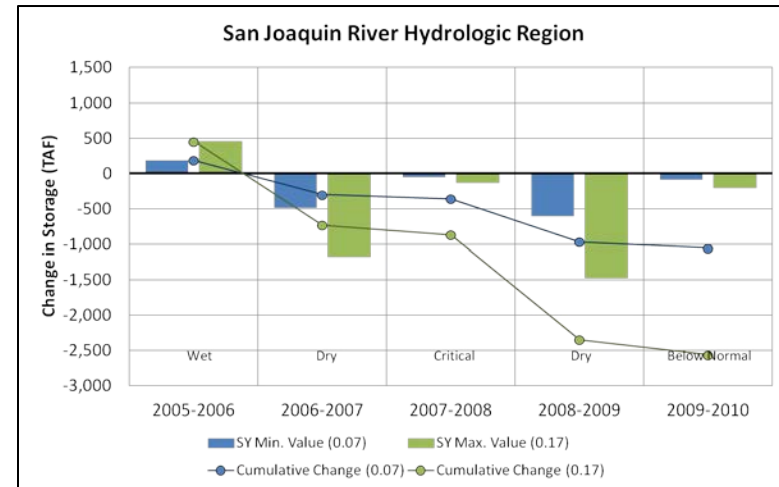
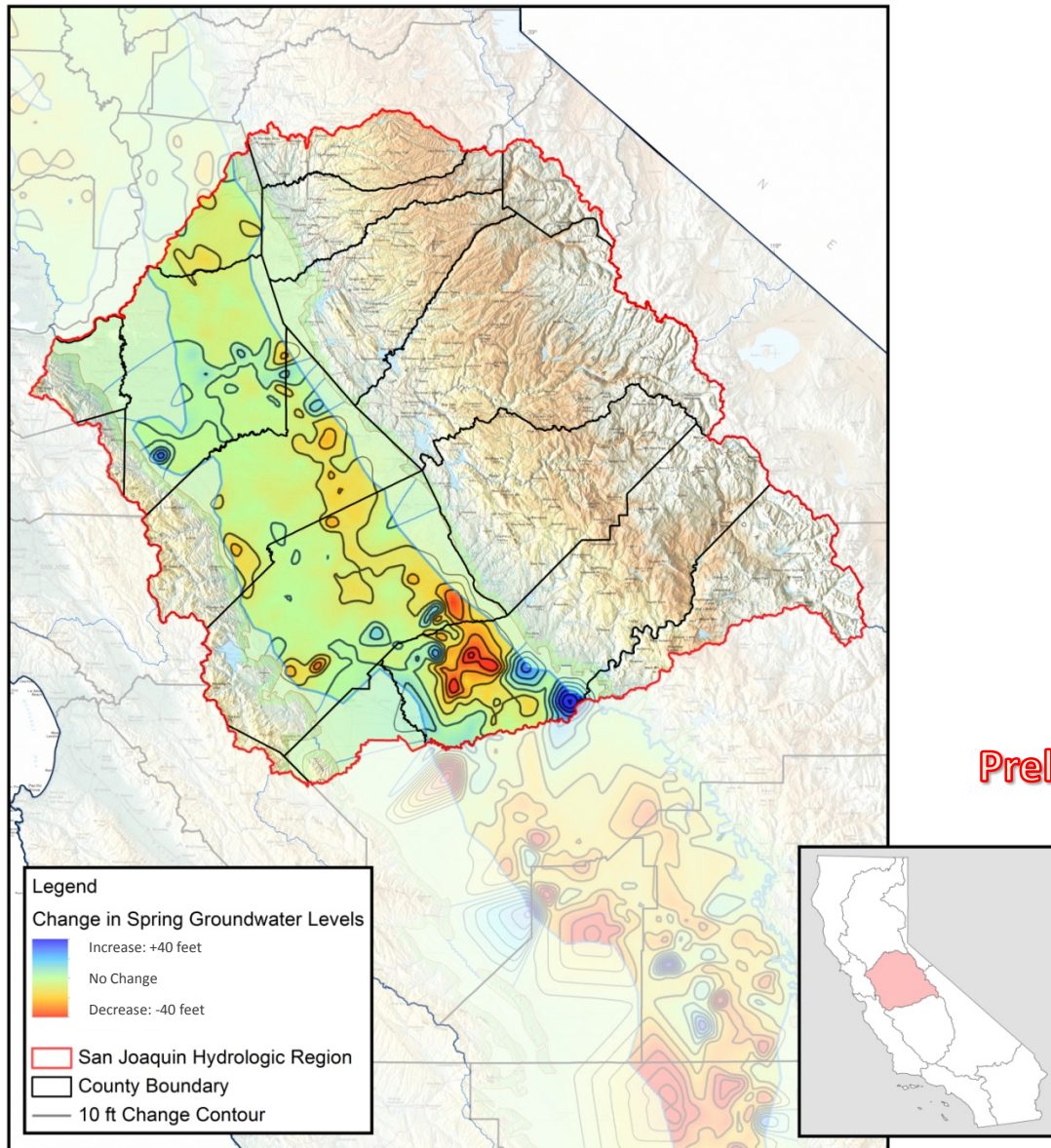


Sacramento Valley Hydrologic Region



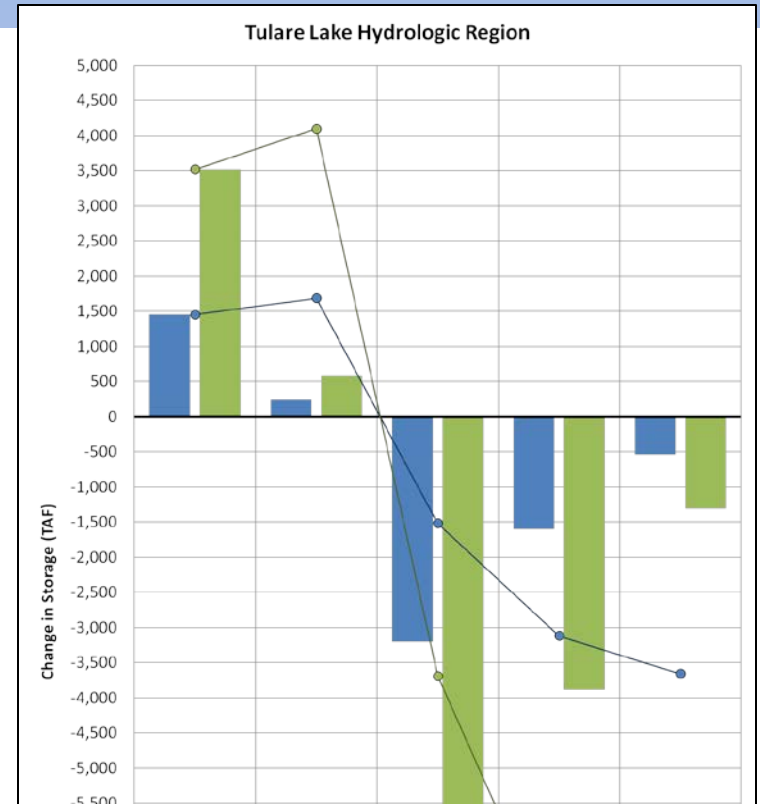
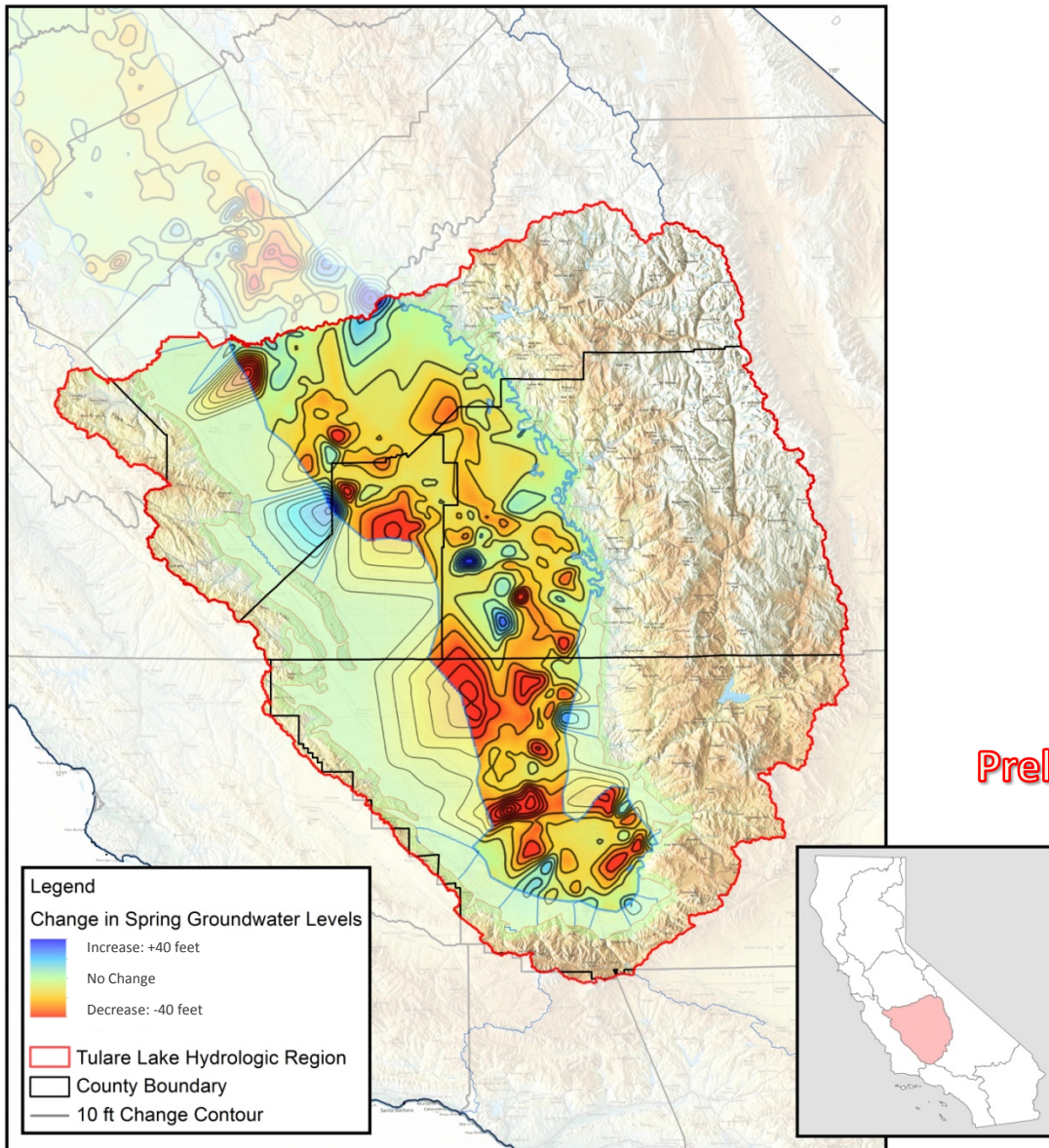
Preliminary Data – Subject to Revision

San Joaquin River Hydrologic Region

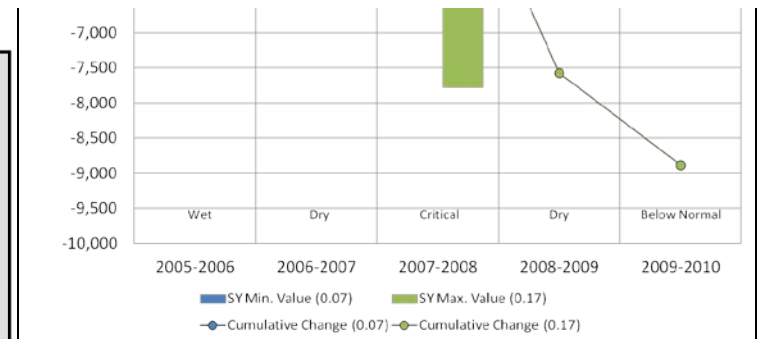


Preliminary Data – Subject to Revision

Tulare Lake Hydrologic Region



Preliminary Data – Subject to Revision



Questions and Wrap-Up

